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16. ABSTRACT

The relationships between eye irritation and oxidant concentrations in the atmosphere have been reviewed. Eye irritation is considered relative to symptoms associated with health effects of photochemical air pollution. Some of the chemical, physiological and psychological aspects of eye irritation are discussed in trying to account for the intensity of eye irritation episodes.

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JOURNAL ARTICLE

Eye Irritation as an Effect of Photochemical Air Pollution

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One of the most annoying aspects of photochemical air pollution, particularly in the Southern California Air Basin, has been eye irritation. The most aggravating combination of driving in heavy traffic in Los Angeles, suffering from tearing and burning of the eyes together with very limited visibility, was a strong motivation for the public to demand that effective control actions be taken.

Although the biological effects associated with photochemical air pollution are difficult to quantitate, more progress probably has been made for eye irritation than other effects. A considerable number of laboratory smog chamber studies have involved measurements of eye irritation by panels.[1-4] Groups of volunteers have also been used in several investigations of eye irritation under ambient air conditions in Los Angeles.[4-6] The laboratory results consistently identify the eye irritants as certain of the organic vapors.

The threshold for eye irritation response has been associated with oxidant concentrations in the 0.10 to 0.15 ppm range.[4-6] This threshold is one of the lower ones for any of the biological effects caused or aggravated by photochemical air pollution. Although eye irritation has tended to increase with increasing oxidant concentrations, neither ozone nor nitrogen dioxide, the two principal oxidants, cause eye irritation. Therefore, oxidant has actually served as a surrogate for the intensity of eye irritation photochemical air pollution. It is important also to note that neither solid particulate matter nor inorganic pollutants such as carbon monoxide or sulfur dioxide are associated with eye irritation effects.[3]

Examination of the plots relating eye irritation to oxidant as well as the experience of individual observers indicates that eye irritation responses are "barely noticeable" to "moderate" for most individuals exposed up to at least 0.20 to 0.25 ppm of oxidant.[5,6] The tearing or burning responses associated with eye irritation are most likely to be experienced above 0.30 ppm.

Eye irritation associated with photochemical air pollution does not appear to be demonstrated to occur in ambient atmospheres in the U.S. outside of Los Angeles. The lack of such experiences is consistent with the very low frequency of oxidant concentrations above 0.25 or 0.30 ppm outside of Los Angeles. It is likely that eye irritation of a "barely noticeable" or even "moderate" level when experienced by a limited fraction of the population of an urban area would not cause a public outcry or perhaps even be definitely associated with photochemical air pollution.

A significant issue is whether eye irritation should be categorized as a health or welfare effect. No statistically significant changes have been detected in pulse rates, respiratory rates, volumes of tidal air, vital capacity, maximum breathing capacity or blood pressure when human subjects have been exposed to concentrations of eye irritants such as formaldehyde and acrolein well above ambient air concentration levels.[7] Examination of the exterior eye of subjects before and after exposure to synthetic smog showed no discernible differences.[3] Even severe eye irritation disappears relatively rapidly with no after effects having been reported.

Exposures to O_3 concentrations of 0.35 to 0.6 ppm of human subjects including some with moderate asthma and/or a history of allergy cause a variety of symptoms including cough, substernal pain, pain on deep inspiration, shortness of breath, headache, and fatigue.[8-10] Eye irritation has not been found to be a significant symptom associated with such O_3 exposures. In the responses of student nurses during photochemical smog in Los Angeles the correlations of symptoms such as cough,

chest discomfort, and headache with O_3 appears to be a direct one.[7] That is, many of the same symptoms are reported from epidemological results as from clinical exposures to O_3.[6,8-10]

While eye irritation is a concurrent response in epidemological studies,[7] it is a response which appears to be unassociated with the respiratory problems, judging from the clinical results.[8-10] Based on the above considerations it would appear more appropriate to treat eye irritation as a welfare effect along with odor, visibility degradation, or plant damage.

Eye irritation in the ambient atmosphere is discussed in detail in the following paper as the summed effect of a number of organic products which are eye irritants and include formaldehyde, acrolein, peroxyacyl nitrates, and probably a number of other organic species. These organic vapors are predominately secondary reaction products from photochemical reactions in air of hydrocarbons (and other organic emissions) with nitrogen oxides.[2] About 20% of the formaldehyde and acrolein may be produced in combustion processes[11] so these primary emissions normally make a minor contribution to eye irritation. However, under conditions of restricted ventilation, vehicular emissions of aldehydes may build up near roadways sufficiently to cause eye irritation.

The yields of these irritants as secondary reaction products are more specifically associated with the hydrocarbon composition than is the case for O_3 yields.[2,12] Therefore, the association between control strategies for hydrocarbons and other organic substances and eye irritation reduction is by no means identical with that for O_3 reduction. In other words, a control strategy to reduce O_3 should not necessarily be expected to have proportional effect in reducing eye irritation.

Although the symptomatology associated with O_3 exposures does not include eye irritation, there may be psychological interactions. It is possible that the adverse effects from O_3 whole body exposures may cause individuals to react differently to the ambient atmosphere than they would in a laboratory exposure of the eyes alone to eye irritants. Irritation to the respiratory tract may cause a different eye irritation response than under controlled laboratory conditions. Odor response may also interact somewhat with eye irritation response.

There also seems to be an apparent aggravating effect caused by forward scattering of light by the photochemically generated aerosols present. This type of effect again has not been readily simulated in laboratory exposures.

Laboratory exposures at realistic concentration levels to eye irritants can cause "barely discernible" or "moderate" eye irritation but usually does not cause severe eye irritation. One possible explanation for such differences compared to very smoggy atmospheres can be as yet unidentified eye irritants in the ambient atmosphere. This possibility is discussed in the following paper. However, the interactions of a physiological or psychological nature discussed above may be at least of equal significance. Such interactions cannot be quantitated today so their true significance is difficult to estimate.

Plant damage and substantial visibility reduction can be associated with photochemical air pollution in a number of areas of the U. S. Some evidence of substernal discomfort in an eastern U. S. site during moderate to heavy exercise while swimming has come to the author's attention. Since both eye irritation and other such symptoms are likely to be only barely above threshold even on typical "smoggy days" in most areas outside Los Angeles, only very carefully designed studies with substantial numbers of human subjects would be likely to provide statistically significant results under such circumstances.

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